The background is a collage of three images: rippling water with a rainbow on the left, a blue semi-truck with a large silver pipe on the right, and green grass at the bottom.

# *Water-use considerations for CA sustainable fuels*

Kevin Fingerman  
UC Berkeley – Energy & Resources  
CA Energy Commission - Dec. 5, 2008

# First, a bit of background

- Research on in-state water impacts of biofuel production

- CARB – LCFS implementation

- *Fingerman et al. (2008). "Integrating water sustainability into the Low Carbon Fuel Standard" CA Air Resources Board*

- Ongoing studies of nation/world-wide effects
- What water sustainability criterion could mean/look like for AB 118

# Sneak preview...

1. We need a holistic, life-cycle water accounting system, and it can be done
  - GHGs are paramount - should not be exclusive
  - Don't want to create new problems
2. Options for incorporating water sustainability into include LCFS/AB118:
  - Determine a "price" for water in Global Warming (GW) units added to Average Fuel Carbon Intensity (AFCI)
  - Charge a price for water use in biofuel production
  - Establish a go/no-go rule for maximum water consumption per MJ of all fuels allowed or incentivized
  - Establish regional rules based on water scarcity



# “Sustainable”

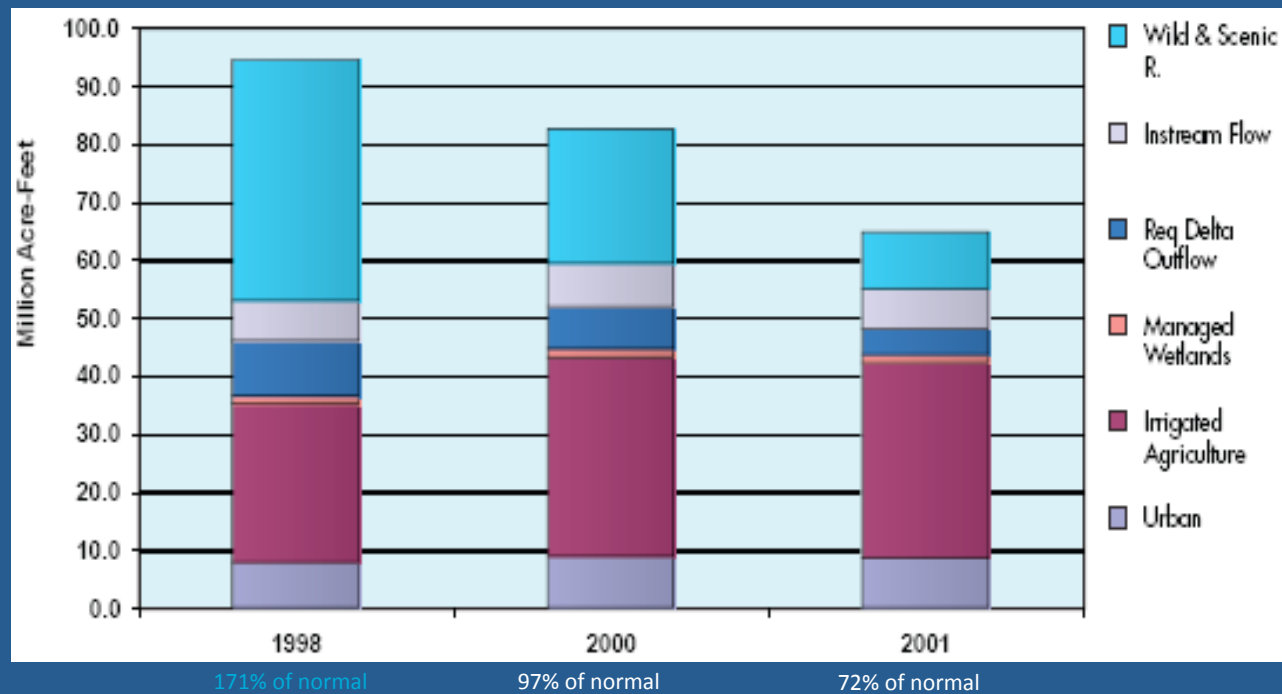
- Unlike for GHG – different things in different places
- Need two numbers
  - How much water was used
  - How much could responsibly be used in location

# Why we care?

- 1/3 of LDCs predicted to have insufficient water resources to meet their needs by 2025
- Agriculture - 70% of withdrawn water, 90% in some places
- Moving water around is GHG-intensive
- Lots of biofuel means...Lots of water...
- We're looking at lots of fuel

# California Water Resources

- \$150+ billion per year agriculture sector
- 84% of developed water used for irrigation
- 1.6 million acre-ft “budget” shortage - largely groundwater overdraft
- Consumptions are regional
- Import a lot of virtual water



# Some Terminology

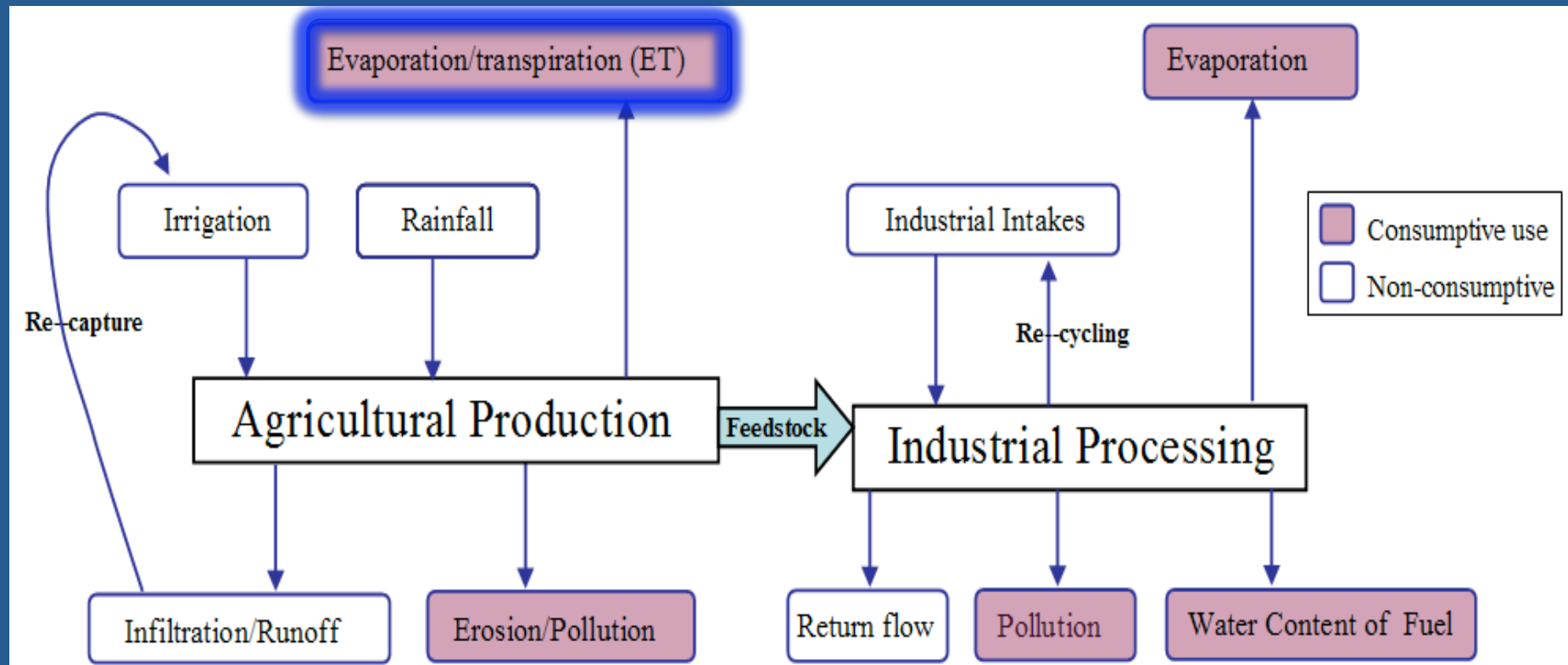
- Embedded Water, Virtual Water, Embodied Water, Water Footprint
  - Blue Water
  - Green water
- Water Consumption (for this hydrologic cycle)
  - *Evapotranspiration*
    - *Evaporation + Transpiration (ET)*
  - *Industrial/biorefinery consumptions*
    - Uses such as cooling and incorporation into finished products. *Not* through-flow
  - *Pollution*
    - Removed from being later utilized productively
- Applied Water

# Current Understandings

- IATP: “Water use by Ethanol Plants”
- Environmental Defense: “Potential Impacts of Biofuel Expansion on Natural Resources”
- FAO: “Water Quality and Environmental Dimensions in Biofuel Production”
- NAS “Water Implications of Biofuels Production in the United States”
- Some popular press
- There’s a BIG hole in all this...

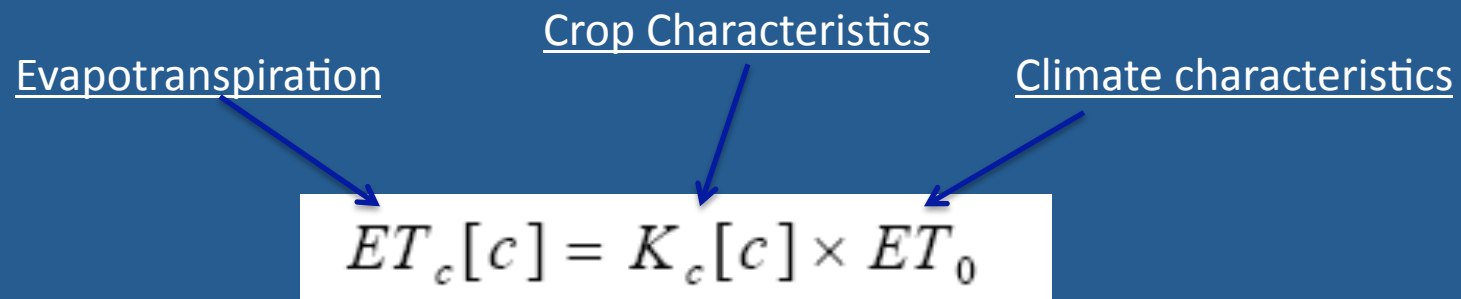


# Water Resources in the Biofuel Life Cycle



# How these calculations are done...

## *FAO - Penman-Monteith Model*



# How these calculations are done...

## *FAO - Penman-Monteith Model*

Climate

Solar radiation

Heat loss into soil

Constant related to humidity

Temperature

“Vapor pressure deficit”

Wind speed

Constant related to humidity

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}$$

The diagram illustrates the FAO-Penman-Monteith equation for reference evapotranspiration (ET<sub>0</sub>). The equation is presented in a white box with a black border. Blue arrows point from descriptive labels to specific terms in the equation: 'Solar radiation' points to R<sub>n</sub>; 'Heat loss into soil' points to G; 'Constant related to humidity' points to Δ in both the numerator and denominator; 'Temperature' points to T; '“Vapor pressure deficit”' points to (e<sub>s</sub> - e<sub>a</sub>); 'Wind speed' points to U<sub>2</sub>; and 'Constant related to humidity' points to γ. The word 'Climate' is positioned to the left of the equation box, with an arrow pointing towards the overall formula.

# Analysis

- Fuel volumes from LCFS study - G10 (biofuel intensive – 10% reduction) scenario
  - 40% in-CA biomass production per Executive order S-06-06
- Scenarios:
  - Feedstock
    - Corn, Sugar beets, High-Yield Biomass (HYB), Low-Yield Biomass (LYB), waste biomass (crop residues, forestry, MSW)
  - Production
    - Maintain percentages, yields
      - First-order assumption
  - Displacements

# Scenarios - Displacements

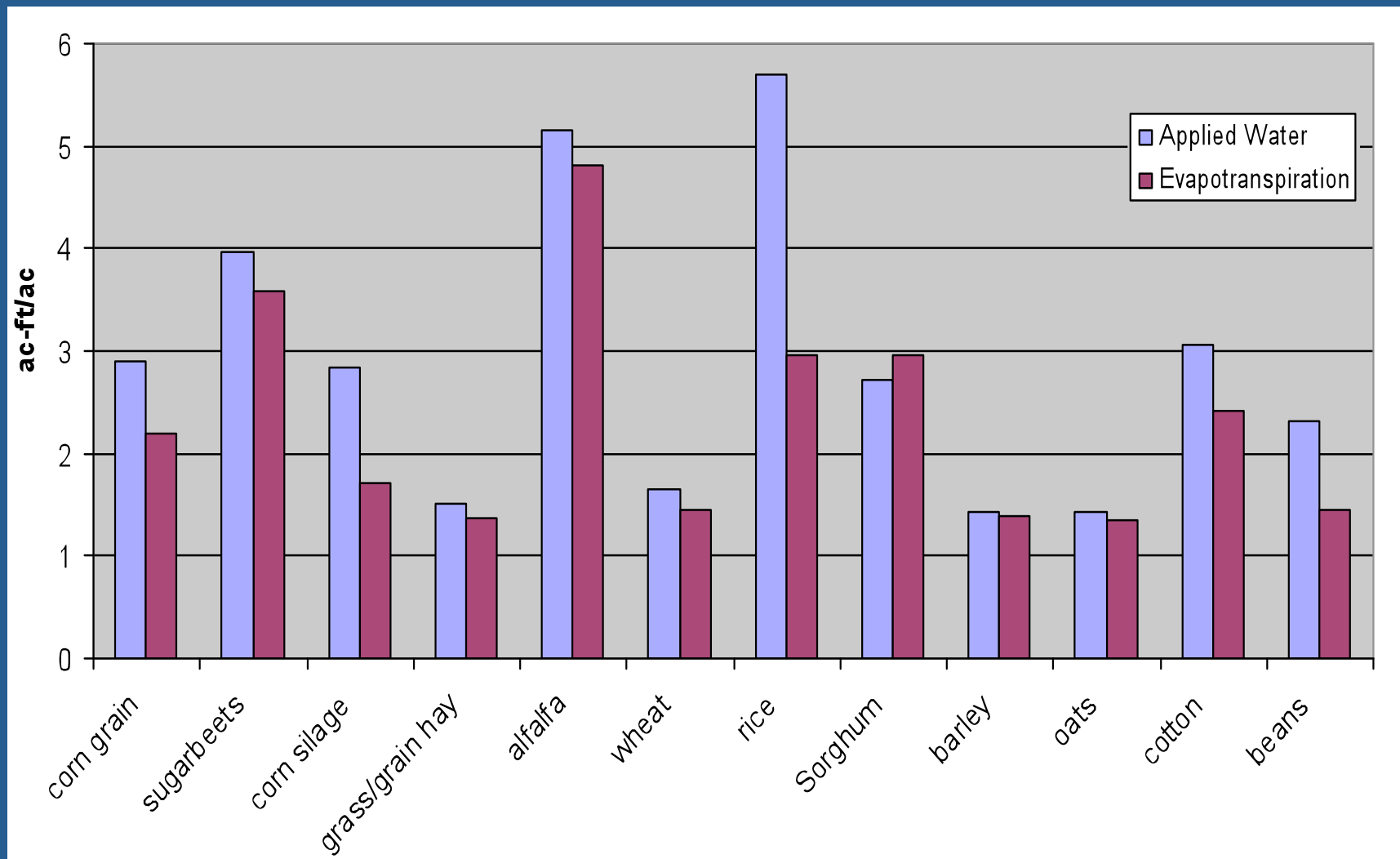
- Field Crops
- Displacing
  - a) County averages
  - b) “Thirstiest” Crops
  - c) “Least Thirsty” Crops
  - d) Pastureland

# Three main results

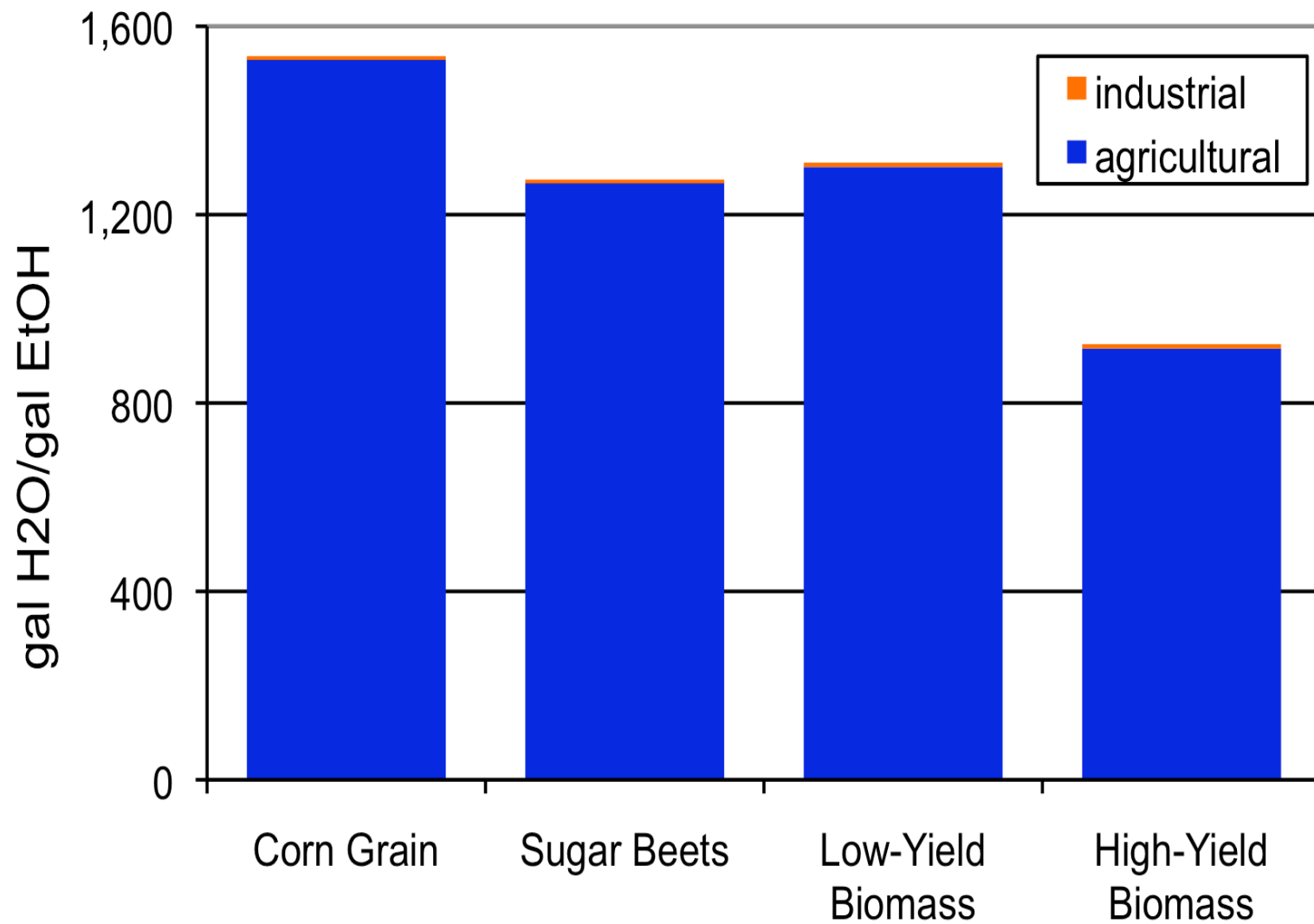
1. Agricultural consumptions are major
2. Different feedstocks consume different volumes of water
3. Also true for the same feedstocks grown in different regions



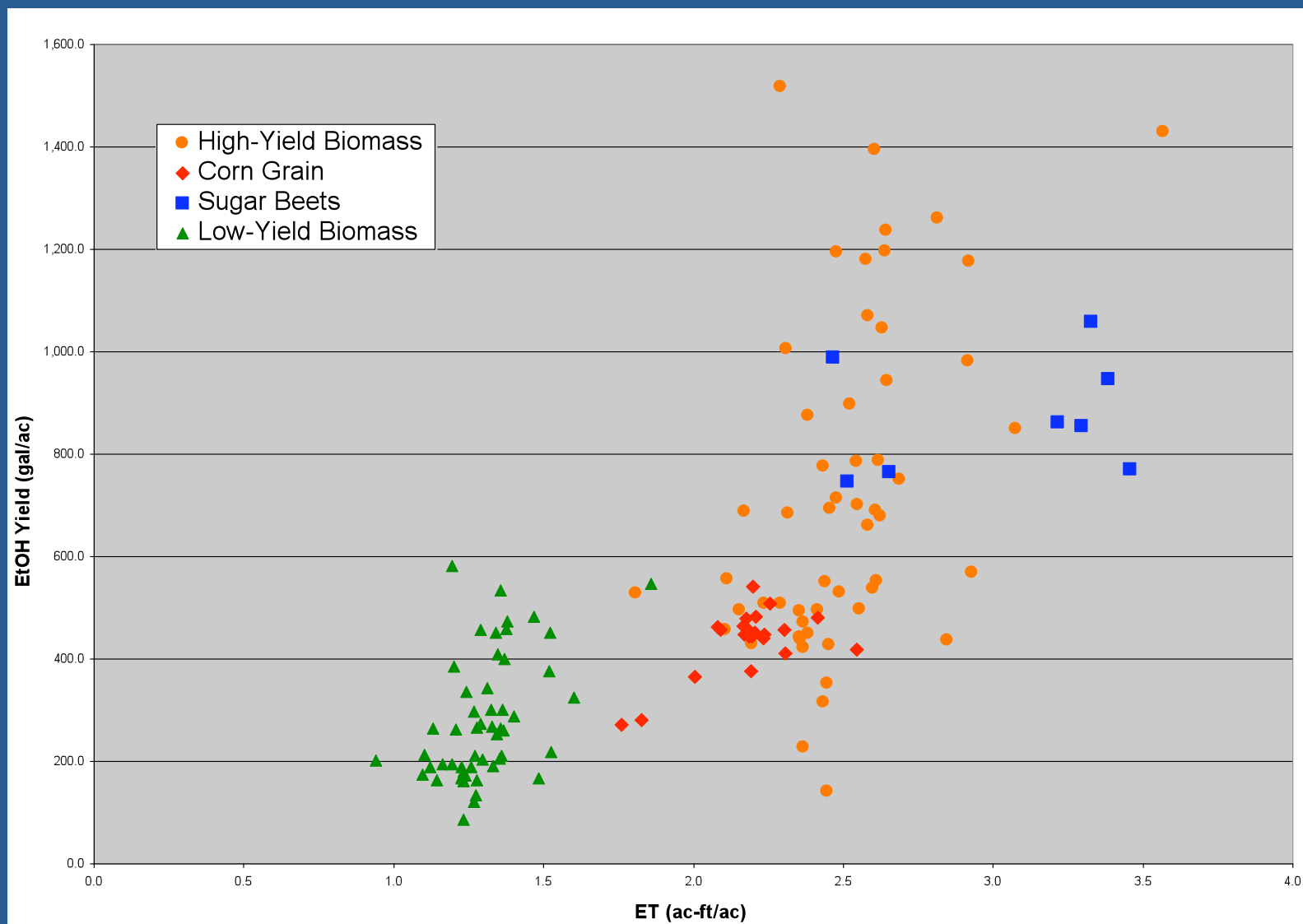
# Water Consumption by California Field Crops



# Fuel Embedded Water

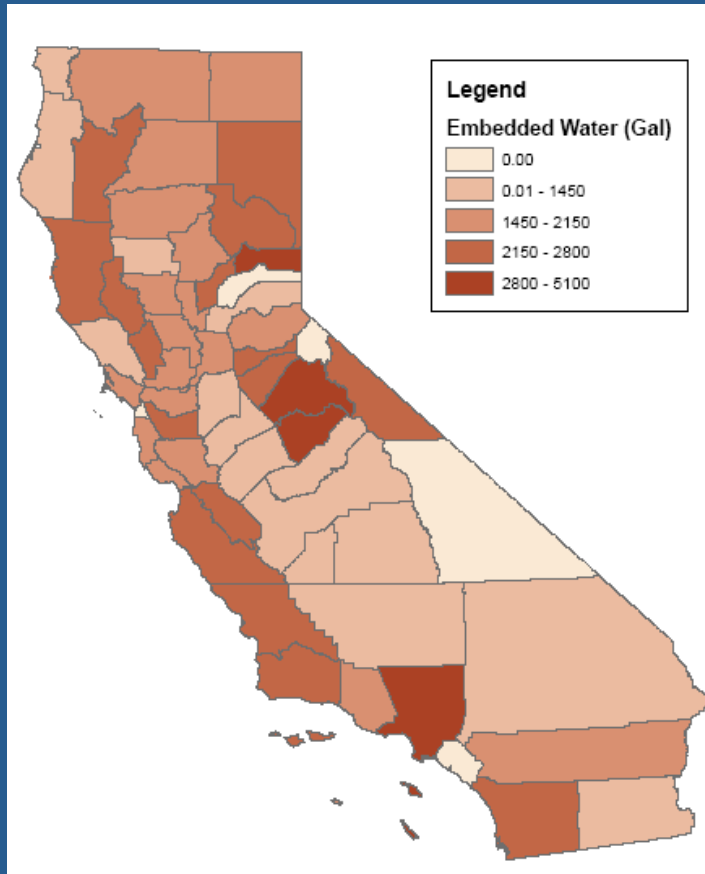


# Yield and ET by County

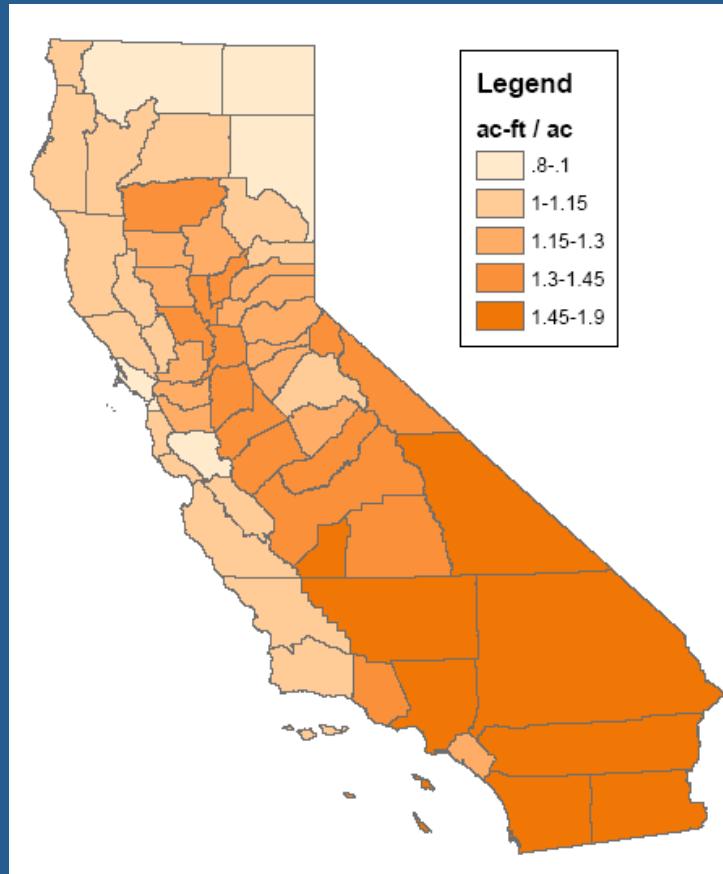


# Water consumption - ethanol from low-yield biomass

Ethanol Embedded Water  
(gallons per gallon ethanol)



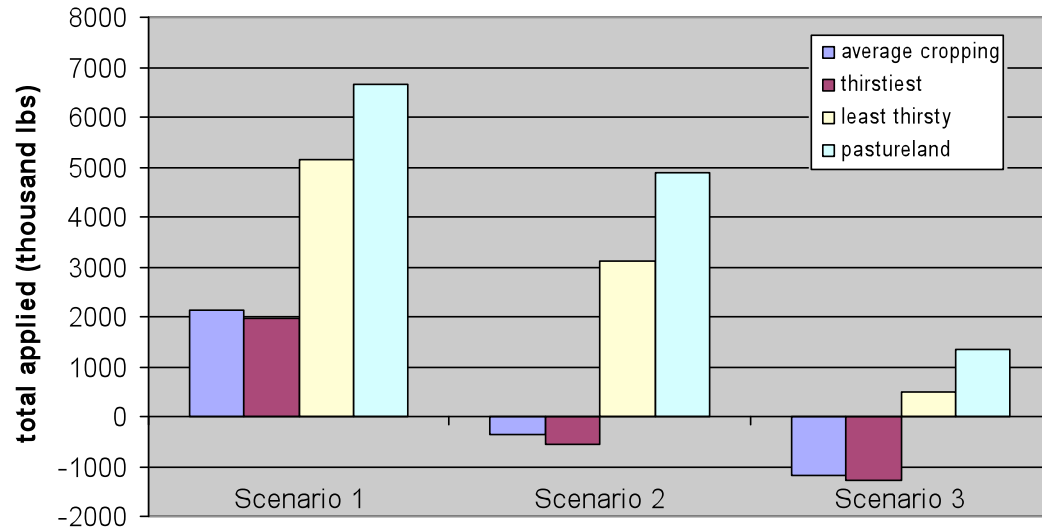
Per-acre consumption  
(ac-ft)



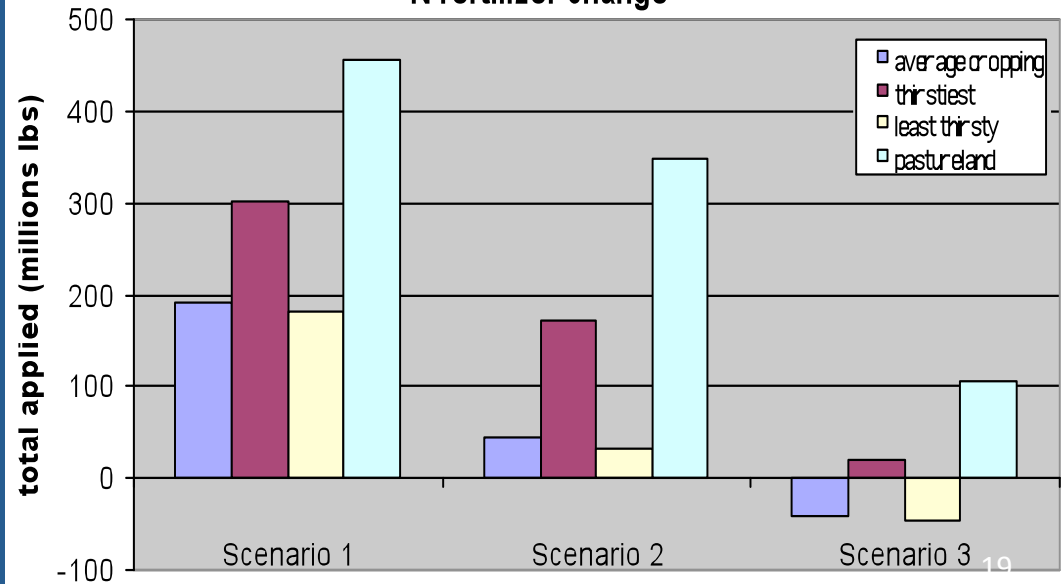
Water consumption (ET) for “low-yield biomass” cellulosic ethanol - analogous to Tilman’s diverse grasslands.

# Chemical Inputs

**"Bad Actor" Pesticide Change**



**N fertilizer change**

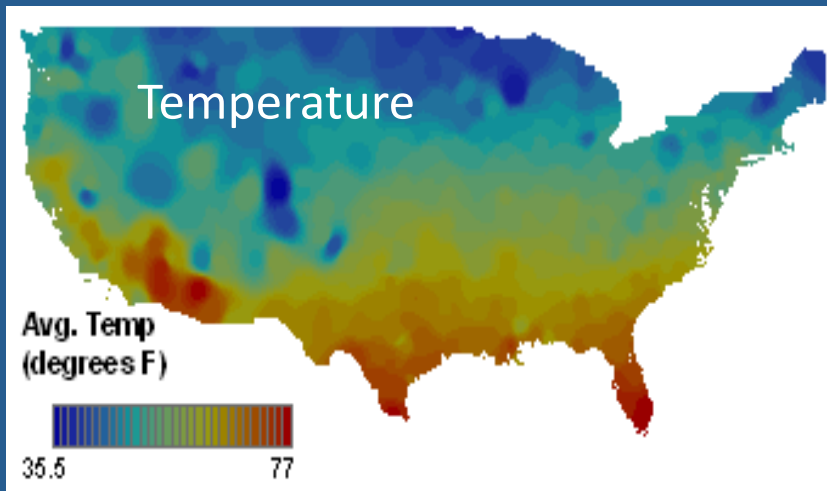


# Potentially Relevant Metrics

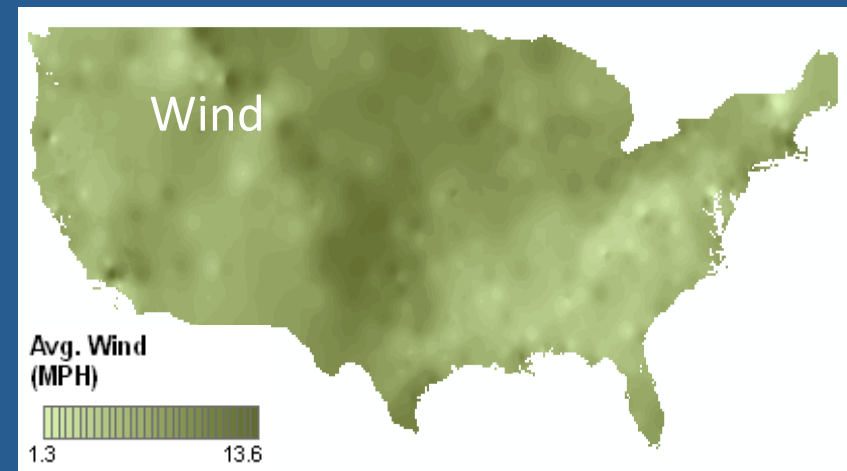
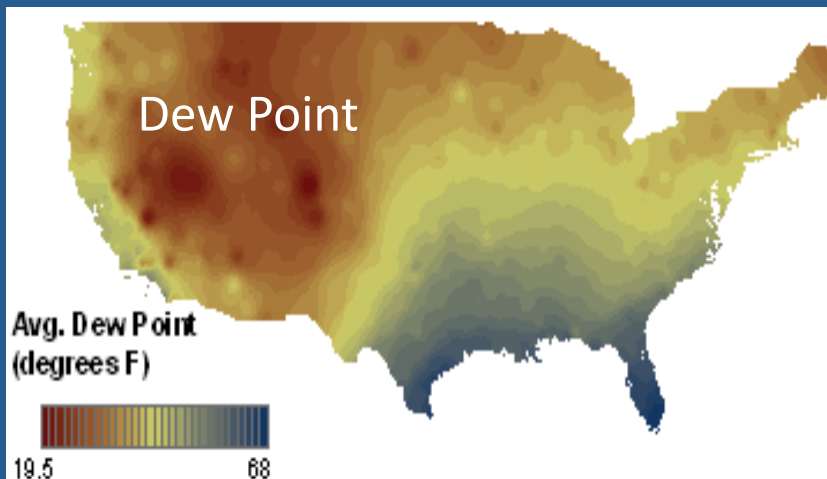
- Water embedded in fuel ( $\text{L H}_2\text{O/L EtOH}$ )
- Water consumed per unit area ( $\text{L H}_2\text{O/acre}$ )
- Water applied ( $\text{L H}_2\text{O/L EtOH}$ )
- Change in water applied/consumed
- Pollution
- Displacement – Indirect “WUC”



# Expanding analysis to other locations/feedstocks



- Modeling evapotranspiration (ET) nationwide using North American Regional Reanalysis (NARR) data out of NCAR
- Uses these interpolated data sets as well as net radiation
- Broaden scope – looking international



# What all this means?

- We can and should have a water accounting system
  - Default/opt-in
- Performance subsidies for best practices (consumption and pollution)
- We should be looking beyond CA
- Regulate siting/design of biorefineries
- Options for incorporating water sustainability into LCFS/AB118:
  - Determine a “price” for water in Global Warming (GW) units added to Average Fuel Carbon Intensity (AFCI)
  - Charge a tax on water use for biofuel production
  - Establish a go/no-go rule for maximum water consumption per MJ of all fuels allowed or incentivized
  - Establish regional rules based on water scarcity



# Thank You!

- Alex Farrell
- Dan Kammen, Margaret Torn, Mike O'Hare
- California Air Resources Board (CARB)
- Morteza Orang (CA Department of Water Resources)
- Jim McKinney (CEC)
- Rich Plevin, Andy Jones, Avery Cohn, Sabrina Spatari



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